HACKTEX VIRTUAL TRAINING MATERIALS

ADVANCED TEXTILES MANUFACTURING INDUSTRY
Learning unit 5
Lesson 2

Management of smart textiles wastes. Recycling and challenges

Innovative smart textiles & entrepreneurship

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Content

Introduction

In the industry, environmental issues have very important role. From the regulations by the government, until in marketing by the expectations of the consumers for more eco-friendly products, sustainability is the key. Therefore, a sustainable textile industry requires sustainable materials, recycling and advanced technologies to achieve a continuous life cycle.

The life cycle of a smart textile is a combination of its two parts the fabric and the devices. The production process, as the rest of the textile life cycle, must incorporates environmental criteria for the reduction of the environmental burden. The low-impacted material selection, alternative processes, improved transport and use, and minimization of impacts in the final treatment of the product's life are few of the considerations of an eco-designed textile.

Therefore, the waste management is one of the main challenging sectors of the textile industry during the production process, as well as, at the end of the life cycle of the product. A integrated guide of priorities to prevention of the waste at the start, to recycling and re-use, to recovery and finally to disposal is necessary of a process that respects the environment.

1. Cycle of life of a smart textile and its ecological impact

1.1. Life Cycle Assessment

The life cycle of a product is starting with the raw material selection, continues with the finished product and the first launch in the market and is finishing with its final withdrawal. In the smart textiles the life cycle includes the life cycle of the fabric and the life cycle of the electronics devices which are two of the most difficult sectors to approach in an eco-friendly way. A detail analysis of this life cycle combination helps to understand the waste potential, energy usage and environmental effects in each of its stage.

For production and withdrawal processes, that already exist, the environmental performance assessment is applied in the framework of implementation of environmental management systems. On the contrary, in new processes of that type, is applied during the phase of design and preparing for permits from authorities. In either case, certain methodologies exist, on the way that the environmental performance assessment should be drafted. It is build upon a set of targets and the relevant indexes. The targets are the areas that are affected by the activity that is assessed, and the indexes are the metrics of the impact, which of course can be negative or positive.

The Life Cycle Assessment (LCA) or life cycle analysis is one of the methodologies used for assessing the environmental impacts of a product from raw material extraction through material processing, manufacturing, distribution, use, repair and maintenance, and disposal or recycling. The phases of LCA make it possible to identify the way that an activity affects the environment and the size of its impact on the different environmental compartments beyond the boundaries of the production plant. A Life Cycle Assessment can be distinguished: in conceptual, that is a qualitative study to identify the most significant potential impacts, the most critical points, therefore, the data used are very general, but it allows us to differentiate the most significant stages of the entire life cycle. In amplified, that takes into consideration only generic data and covers the Life Cycle in a superficial way, followed by a simplification, focusing on the most important stages, and a reliability analysis of the results and in complete Life Cycle Assessment, that is a detailed qualitative and quantitative analysis, which considering all stages and all available data.

At the end, after the selection of type of LCA must be establish the scope of the analysis. The scope of the LCA can be gate-to-gate, which focuses only in one process of production chain, cradle-to-gate way, which is an assessment of a product life cycle from resource extraction (cradle) to the factory gate, cradle to grave, which covers the range from extraction of raw materials from the earth to manufacturing, product use and recycling/disposal at the end, or by cradle-to-cradle, which has the scope closed the loop production.

1.2. Ecological impact

Ecological impact, or footprint, of an activity, is an index that aggregates the whole range of environment changes provoked by this activity. This index indicates the quantity of land or sea productive area that is required, in order to produce the resources that are consumed and in order to eliminate the waste produced. In this way, we can understand the units of area that the activity harms in relation to the area of the ecosystem. It is based on the concept of the carrying capacity of the ecosystems, which is the inherent capacity of the systems to provide material as well as remediate environmental harm.

For example, if an activity has a high environmental impact in a lake is an indication that this eco system will not be able to provide enough or remediate the harm. Therefore, that activity is not sustainable in that eco system. That is controversial according to the theory that companies to emit gaseous pollutants, instead of reducing their emission; they finance tree plantations in order to balance in a positive way their ecological footprint. This misunderstanding happens because the index of environmental impact is simplified and not analytical, so, since the environmental footprint sums up all aspects of environmental impact to one single index, business can tradeoff between the actions that they should do in order to reduce their footprint.

Want to learn more about this topic?

Understanding Product Environmental Footprint and Organisation Environmental Footprint methods, European Comission 2021:

https://ec.europa.eu/environment/eussd/smgp/pdf/EF%20simple%20guide_v7_clen.pdf

2. Sustainable management and development

2.1. Sustainable development

Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs. By the year 2050, it is estimated that our global population will likely reach 9 billion people, so, sustainable development practices indicate to the countries how to grow in way to delay climate change and to adapt to the challenges its posed, in order to protect important natural resources for ours and future generations. The term sustainability refers to four distinct areas: human, social, economic and environmental.

Human sustainability aims to maintain and improve the human capital in society. Investments in the health and education systems, access to services, nutrition, knowledge and skills are all programs under the umbrella of human sustainability. Natural resources and spaces available are limited and there is a need to balance continual growth with improvements to health and achieving economic wellbeing for everyone.

Social sustainability is the high quality of development of the communities provided the supply of housing required to meet the needs of present and future generations and created accessible local services that reflect the community's' needs and support its health, social and cultural well-being.

A strong, competitive economy is sustainable when ensuring that sufficient land of the right type is available in the right places and at the right time to support growth and innovation.

Environmental sustainability contributes to protecting and enhancing our natural and developed environment, while helping to improve biodiversity, use natural resources wisely, minimizing waste and pollution, and adapting to and helping to decrease climate change, including a global shift to low-carbon economy.

Applying these four strategic sectors, simultaneously, interacting with one another in a consistent, committed effort, to urbanization, agriculture, infrastructure, energy, water and transportation creates a sustainable development human system.

The challenge of sustainable development is to move forward in such way that every human will be able to enjoy a substantial quality life without being detrimental to natural resources of the planet.

Figure 1. Textile image from pexels.com

2.2. Eco-design and waste management

The eco-design is defined the design plan, which it contains: the design for sustainable sourcing- with the incorporation of recycles and recyclable materials, the use of renewable energies and the choice of local providers, the design for optimized resource use- saving energy, water and resources in overall, improving processes and applying cleaner technologies, the design for environmentally sound and safe product use- using less polluting raw materials, selecting materials with low environmental impact and free of toxic products, optimizing packaging and minimize the environment impact of transport, the design for prolonged product use- thinking cyclically to keep the product in the best possible condition for as long as possible, establishing fair and responsible business practices, introducing conceptual product improvements, notifying the environmental requirements or the correct use and reuse of the product extending their life even more, and, at last, the design for recycling- with the purpose the easier separation of the components, the simpler identification of materials, to reduce the waste generated and improve its final management.

The management of the waste focuses to prevention, reduce, re-use, recycling, recovery and final disposal. To introduce waste management, it is strictly necessary to define a conceptual framework designed to guide and rank waste management decisions at both the individual and organizational level. The process of waste management, for be sustainable, must be approached in an integrate way from the start of the production until the end of the life of the product.

The hierarchy of the wastes based on six priorities ranked in terms of what is best for the environment and captures the progression of a material or product through successive stages of waste management and represents the latter part of the life cycle for each product. Those six priorities are the prevention, the reduce, the reuse, the recycle, the recover and the dispose. Analytically, preventing waste generation involves redesigning products and processes and/or changing societal patterns of consumption and production. Reducing waste means to reduce the use of raw materials avoiding disposable or single-use goods, procuring materials that are recycled or can be recycled, repaired or reused and optimizing inventory to prevent perishable goods from going to waste. The preparation for reuse extends the products life before they become waste. Preparing materials for reuse in their original form is the third-best approach to waste management. Aside from reducing landfill impact, reusing waste also allows companies to avoid spending money on new goods or virgin materials or paying a provider to dispose the waste. The recycling, from the other hand, is the use of waste materials with purpose to turning them into products, materials or substances whether for the original or other. It is the fourth step of the waste management hierarchy because of the extra energy and resources that go into creating a new product. For example, scrap paper can be recycled, but the process requires water and electricity to transform it into pristine paper products. In cases that it is not possible the recycling, the recovered energy or materials from waste through processes such as incineration, anaerobic digestion, gasification or pyrolysis can be useful to use or fed back into the electricity grid. At last, the disposal is the processes to discard of waste trough landfilling, incineration, pyrolysis, gasification and other solutions to dispose textile waste. Although, the approach between consumer and producer must be separated because of the quantity of waste. Specifically, more than 90% of the collection comes from clothing and footwear containers, both on the street and in public or private establishments, including municipal waste. On the contrary, concerning companies, for specific collection associated with economic activities, bulk collection is carried out at the production site, where the textile waste has previously been prepared in sacks, cages, etc.

Want to learn more about this topic?

Sustainability Innovation in the Textile Industry: A Systematic Review, by Budi Harsanto, Ina Primiana, Vita Sarasi and Yayan Satyakti.

https://www.mdpi.com/2071-1050/15/2/1549

3. Waste types and recycling methods

3.1. Waste types

Textile and fashion waste can be classified into different types based on their source of generation, toxicity, disposal and discarding or categorized by their nature (solid or soft) or the phase of the product life cycle that they are produced. Pre and post-consumer wastes are the waste generated at various levels after usage of the finished product by end consumer and could be any clothing or household article, which has been discarded or not in use for any reason like being worn out, damaged or outgrown. Pre consumer textile waste, according to Council for Textile Recycling, is the waste generated during production by processing fibers, and the production of finished yarns and textiles, technical textiles, nonwoven, garments and footwear, including offcuts, selvages, sheerings, rejected materials and/or B-grade garments.

Another classification of waste in production is soft and hard waste. Soft waste is the waste in which fibers are relatively open structure and can be reused at an earlier feed stage, it's generated from bloom to the ring frame and is reusable for producing a low quality of yarn; Hard waste is the waste in which fibers are packed in a closed structure and need additional operations before reusing them with soft waste. These wastes are produced in ring frame, winding, weaving preparatory and during weaving operations. The majority of solid waste originates from other sources during operations like transportation, bale openings, servicing process and housekeeping. The waste under this category includes tubes, pallets, cones, containers, drums, plastic wrap, corrugated cardboard, seam waste, paper waste, bags, shipping cartons Textile packaging contributes a significant amount of solid waste that damages the environment. The industry has responded in different ways to reduce the waste generation by promoting recycling, reuse, energy recovery, minimization, and using novel compostable polymers.

The toxicity of the textile wastes is, also, a parameter of classification. Colors, metals, phenols, certain surfactants, toxic organic compounds, pesticides, as well as phosphates are some of the hard to treat wastes hazardous, toxic and dispersible waste with characteristics that demand different pollution prevention and treatment approach. Hard to treat wastes are wastes characterized by their persistent, resist treatment, or interfere with the operation of waste treatment facilities. Hazardous wastes, a subgroup of hard to treat wastes, are the metal, chlorinated solvents, non-degradable surfactants and other non-biodegradable or volatile organic materials. Dispersible wastes in textile wet processing are the following: Print paste, lint, coating operation, solvent, waste stream from continuous dyeing, printing, finishing etc.

At the end, high volume wastes are, also, one of the challenges in waste management of the textiles industry. High volume wastes can be the water from preparation and dyeing stages, alkaline wastes from preparation, salt, cutting room waste, knitting oils and warp sizes. These wastes can be reduced by recycle or reuse as well as by process and equipment modifications.

Table 1. Table caption

a	*b*	*c*	*d*	*e*
s	*12*	*56*	*90*	*34*
f	*34*	*78*	*12*	*56*

Adapt table if necessary.

3.2. Recycling methods

Textile recycling is the action of reprocessing pre or post-consumer textile wastes and use it in new textiles or non-textile products.

There are two recycling processes, the closed and the open loop. In the first process, the recycled textile material is used in an identical product. In the opposite, in an open loop recycling process, the textile recycled material is used in a different product. In general, the textiles can be recycled into fibers, into polymers, into monomers or into molecules different from monomers; the nature of the final recycled product requires different treatments, so, a subcategory of a recycling method is the mechanical and/or chemical processes.

The wastes that come from pre costumer deposits, like industries, are production wastes, unfinished or unsold products. In that case, the composition of the textile is homogeneous and known, something that makes easier the recycle. In the other hand, the post-consumer wastes are mixed and heterogeneous, something that makes the recycle process complicated and more difficult. Moreover, the used fibers could be damaged, and so more fragile. However, in both cases, to recover the fibers, is necessary to separate the textiles by color and material and to remove the hard and electronic parts from the rest of the clothes, as in coated or laminated textiles. After that, the textile must be cut into little pieces, which enter in a shredding machine with rotating metal pins drums to open the textile and recover the fibers. The output is a mix of fibers with different lengths and the shorter ones can be used as flocks in an open-loop application. Although, to create an identical new product from those fibers, so to have a close-loop application, is necessary to mix the, already used, fibers with new ones to ensure the mechanical properties of the yarn.

For thermoplastic materials, another way of recycling is to covert the textile into polymers. That conversion requires a mechanical or a chemical process. In the mechanical process, the pieces of textiles are melted and spun directly or recycled into granulates. In that case, the material must be as pure as possible. The output is granulates that can be used in the production as raw materials, in an open or close loop process. As in fibers collection, the polymers degradation is inevitably, so, is necessary to add new material for the creation of a yarn with the same mechanical characteristics. In chemical dissolution process, the textile pieces are dissolved in a specific solvent, where the fibers are converted from synthetic polymers to cellulosic fibers. The output is a dissolved polymer, which can be spun using a solvent spinning process to recover a fiber of the same nature as the input one. The advantage of this process is it can handle contamination and fiber blends, as it is possible to dissolve only a part of the blend. It is also a solution to remove coatings, dissolving only the fiber or only the coating.

Another recycle way is to convert the synthetic polymers of textile into monomers by a chemical depolymerizing process, where pieces of the textile can be depolymerized in various ways to create output monomers, with the same quality as the virgin ones, that can be used in industry of textiles or plastics in an open or close loop process. This is an infinite recycling process, because there is not degradation in quality and the impurities can be well removed from the texture from the moment that they cannot be depolymerized.

From the other hand, in recycling textile into molecules there are chemical processes as pyrolysis, composting and fermentation. In pyrolysis, the pieces of textiles are heated at a very high temperature to be degraded and converted to gas, oil and carbon. The input is any organic carbon-based material, including biomass plastic and textiles and the output are various mixed gases, oils or carbon that can be used as fuel or as feedstock in the production of chemicals. This application can be, only, an open loop application, has as advantage to recycling fibers or blends, which cannot be recycled otherwise by other used technologies, but is not developed on an industrial scale in the textiles. In the processes of composting and fermentation recycling, microorganisms transform organic material into molecules, thanks to fungi, yeast or bacteria in the presence of oxygen, water and nitrogen. The input could be cellulose rich feedstock and mixed textile wastes and the output is a range of fuel molecules, chemicals and non-cellulosic fibers that can be used as fuel or as input in other industries.

In conclusion, in the sector of the smart textiles is important to understand and approach the textile with its two different natures. In the recycle procedure should be separate the fibers part of the texture from the electronic parts in order to improve the processes that already exist today for the simply textures in one part and the devices in the other. Furthermore, selecting the right recycle process the output product can become the raw material for the production of other simpler or more complexed products.

Want to learn more about this topic?

Waste Disposal Strategies in Textile Manufacturing, by Md. Shazzat Hossain, Md. Abdus Samad, Mohammad Ullah

https://textilelearner.net/waste-disposal-strategies-in-textile-manufacturing/

Sustainable Recycled Polyester (PET) in Textile, by Amirsuhel Aslam Desai Danwade

https://textilelearner.net/sustainable-recycled-polyester-in-textile/

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Partnership

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TUIASI - Universitatea Tehnica Gheorghe Asachi din Iasi
www.tuiasi.ro

AEI Tèxtils - Agrupació d'Empreses Innovadores Tèxtils
www.textils.cat

CIAPE – Centro pre l'Apprendimento Permanente
www.ciape.it

CRE.THI.DEV - Creative Thinking Development
www.crethidev.gr

TITERA - Technically Innovative Technologies
www.titera.tech

UB – Högskolan i Boras
www.hb.se

UNIWA - Panepistimio Dytikis Attikis
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